Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Multidimensional Digital Inequality in Rural and Urban District Hospitals in Ghana: Implications for Health Equity

Abdul Wadudu Braimah

awbraimah@gmail.com

Komfo Anokye Teaching Hospital

Peter Darko

Peadato Limited Company

Rashida Yakubu

Ghana Health Service

Research Article

Keywords: Digital health equity, Digital divide, Rural–urban disparities, Digital health access, Healthcare workers, Provider-level inequality, Health information systems, Ghana

Posted Date: October 29th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11536250/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

Digital health technologies are increasingly deployed to strengthen healthcare delivery in low- and middle-income countries, yet unequal access to the material resources, skills and opportunities required for meaningful use may reproduce existing inequalities. Evidence on provider-level digital inequality between rural and urban healthcare settings in sub-Saharan Africa remains limited. This study examined rural-urban differences in multidimensional digital health access among healthcare workers in Ghana's public district hospitals.

Methods

A comparative cross-sectional survey was conducted among 384 healthcare workers from 20 public district hospitals, comprising 10 rural and 10 urban hospitals. Structured questionnaires measured motivational, material, skills and usage access, and perceived digital health benefits. Rural-urban differences were assessed using independent-samples t-tests, with Mann-Whitney U tests as sensitivity analyses. Partial least squares structural equation modelling examined associations among access dimensions and perceived benefits.

Results

Motivational access did not differ significantly between rural and urban respondents (2.87 vs. 2.99, $p = .201$). Significant differences were observed in material access (2.25 vs. 3.47, $p < .001$, $d = 1.74$), skills access (2.69 vs. 3.23, $p < .001$, $d = 0.69$), usage access (2.55 vs. 3.20, $p < .001$, $d = 0.85$) and perceived digital health benefits (2.71 vs. 3.10, $p < .001$, $d = 0.52$). Material access was positively associated with skills access ($\beta = 0.513$, $p < .001$) and usage access ($\beta = 0.282$, $p = .003$), while skills access was positively associated with usage access ($\beta = 0.362$, $p < .001$). Usage access had the strongest direct association with perceived benefits ($\beta = 0.548$, $p < .001$). Skills access was not directly associated with perceived benefits ($\beta = -0.050$, $p = .592$).

Conclusions

Rural-urban digital inequality extends beyond connectivity to encompass material resources, digital skills, patterns of technology use and perceived benefits. The findings suggest that equitable digital transformation requires attention to the conditions that enable healthcare workers to develop capabilities and translate digital access into meaningful use. Addressing multidimensional provider-level inequality may therefore represent an important upstream consideration for digital health equity in Ghana and comparable low- and middle-income health systems.

Introduction

Digital health technologies are increasingly being integrated into health systems to support healthcare delivery, clinical decision-making, communication, health information management and access to services (1,2). Electronic health records, telemedicine, mobile health applications and other digital platforms have expanded the ways in which health services can be delivered and coordinated, particularly in settings where geographical distance and limited healthcare resources constrain conventional service delivery (3–5). However, the expansion of digital health does not necessarily guarantee equitable access to, use of, or benefit from these technologies. Differences in infrastructure, connectivity, digital capabilities and opportunities for meaningful use can create or reinforce inequalities within health systems (6–8).

This concern extends the conventional understanding of the digital divide beyond whether individuals or organisations possess physical access to technology. Digital inequality is conceptualised as a multidimensional process involving motivational access, material access, skills access and usage access (6). These dimensions represent successive but interacting conditions through which individuals and organisations appropriate digital technologies. Subsequent empirical research similarly demonstrates that inequalities in physical and material resources can coexist with differences in digital skills, patterns of technology use and the benefits derived from digital technologies (9). Consequently, the presence of digital infrastructure alone cannot be assumed to produce equitable digital participation or outcomes.

The equity implications of these differences are particularly important in health systems where digital technologies are increasingly used to support clinical and administrative activities (10,11). Health workers require appropriate devices, reliable connectivity, electricity, functioning digital systems and technical support to use digital health technologies effectively, while also requiring the skills necessary to integrate these technologies into routine professional practice (6,12,13). Evidence from digital health implementation further suggests that limitations in infrastructure, connectivity and digital capabilities can constrain the effective use and sustainability of digital technologies, particularly in resource-constrained settings (14). Where these conditions vary systematically across health facilities, digital transformation may therefore reproduce existing geographical inequalities rather than reduce them (8). From this perspective, digital health equity requires attention not only to whether technology is available, but also to whether health-system actors have comparable opportunities to access, appropriate, use and derive meaningful benefits from digital technologies (9).

These challenges occur within a broader digital health environment characterised by uneven system integration and implementation capacity. Ghana has made progress in the digitalisation of health services, including efforts to expand digital health platforms and strengthen the integration of health information systems, although important challenges remain (15). These challenges have important implications for equity because the capacity of health facilities to implement, use and sustain digital health technologies may depend on the resources and institutional conditions available within their

geographical and organisational contexts. Consequently, when digital technologies are introduced without adequately addressing differences in the resources and capabilities required for their appropriation, digital transformation may reproduce existing inequalities within the health system rather than reduce them (9,13).

Despite growing evidence on digital health implementation in Ghana, important questions remain about how digital inequalities are distributed across health facilities and whether these inequalities extend beyond differences in physical infrastructure. Existing Ghanaian studies have examined specific digital health interventions, implementation barriers, telemedicine, health information system integration and broader governance challenges (13,15). This evidence provides important insights into the constraints affecting digital health implementation, but it offers limited understanding of whether rural and urban public district hospitals experience systematic differences across multiple dimensions of digital access. Moreover, limited attention has been given to how differences in these dimensions may be associated with the benefits that health workers perceive from digital technologies. Examining these relationships is important because differences in infrastructure alone may not fully explain digital inequalities. A facility may possess digital systems but lack the connectivity, technical support, skills or organisational conditions required for their effective appropriation and routine use (9). Consequently, a multidimensional examination of digital access is needed to understand whether geographical differences in health-system digital capacity translate into differences in technology use and perceived benefits.

This study addresses this gap by examining digital health equity across rural and urban public district hospitals in Ghana through the lens of Van Dijk's Resource and Appropriation Theory (16). It conceptualises digital access as a multidimensional process involving motivational, material, skills and usage access and examines how material access, skills access and usage access are related to perceived digital health benefits. The study further investigates whether these dimensions and their relationships differ between rural and urban district hospitals. By focusing on comparable public district hospitals, the study separates geographical context from differences in hospital level and provides a more focused examination of the rural-urban digital divide within Ghana's public health system.

Theoretical Foundation

This study is grounded in Van Dijk's Resource and Appropriation Theory, which conceptualises digital inequality as a multidimensional process rather than a simple distinction between those who have and do not have access to technology. Van Dijk (16) identifies four successive forms of access: motivational access, material access, skills access and usage access. Motivational access concerns willingness and interest in using digital technologies, material access concerns the availability of devices and network connections, skills access concerns the capabilities required to use technologies, and usage access concerns the actual opportunities and patterns of technology use.

The theory proposes that digital access develops through an appropriation process in which different forms of access are interconnected. Van Deursen and van Dijk (17) empirically demonstrated that motivational, material, skills and usage access remain relevant and interact in shaping digital inequalities. Thus, material access does not necessarily guarantee meaningful use because users also require appropriate skills and opportunities to apply digital technologies.

The framework is particularly relevant to healthcare because digital health technologies require both technological resources and human capabilities for effective incorporation into professional practice. In this study, the framework is extended to examine whether differences in digital access among healthcare workers are associated with differences in digital health use and perceived benefits. Motivational access is examined as an important dimension of digital inequality, while material access, skills access and usage access form the core explanatory pathway.

Material Access and Skills Access

Material access represents the resources required to participate in digital environments, including appropriate devices, connectivity and supporting infrastructure (18). In a health-system context, access to functioning devices, reliable connectivity, electricity, digital systems and technical support provides the conditions within which healthcare workers can acquire and apply digital capabilities (19,20). Where these resources are inadequate, opportunities to develop and practise digital skills may also be constrained.

The relationship between material conditions and digital capability is consistent with Van Dijk's (21) appropriation framework, in which material access precedes skills access. Soomro et al. (12), applying Van Dijk's framework to professional ICT access, similarly distinguish physical access from operational, informational and strategic skills. Therefore, the study proposes:

H1

Material access is positively associated with skills access among healthcare workers in public district hospitals.

Skills Access and Usage Access

Skills access concerns the capabilities required to operate, understand and strategically use digital technologies. Van Deursen and van Dijk (17) distinguish different forms of digital skills, while their empirical work demonstrates that inequalities in digital skills remain important even as basic technological access becomes more widespread. Operational, informational and strategic skills enable users to move from basic interaction with technology towards purposeful and effective use.

In healthcare, these capabilities are particularly important because digital systems are embedded in professional tasks rather than used solely for general information access. Health workers must be able

to navigate systems, enter and retrieve information, assess digital information and apply it to professional activities (22). Accordingly, the study proposes:

H2

Skills access is positively associated with usage access among healthcare workers in public district hospitals.

Material Access and Usage Access

Material access may also influence digital technology use directly. Even when healthcare workers possess adequate digital skills, unreliable connectivity, insufficient devices, power interruptions, unavailable systems or inadequate technical support can prevent them from using digital technologies consistently (23). Van Deursen and van Dijk (17) argue that material access remains relevant throughout the appropriation process rather than becoming irrelevant once users acquire digital skills. This relationship is particularly relevant in resource-constrained health systems. Wang et al. (24) found that facilitating conditions were the leading facilitator of actual digital health technology use among health workers in LMICs. Similarly, evidence from Ghana identifies infrastructure and connectivity limitations as continuing constraints on digital health implementation (13). Thus, the study proposes:

H3

Material access is positively associated with usage access among healthcare workers in public district hospitals.

Usage Access and Perceived Digital Health Benefits

Usage access represents the extent to which individuals have meaningful opportunities to use digital technologies and incorporate them into their activities. Van Deursen and van Dijk (17) demonstrate that digital inequality increasingly manifests in differences in how technologies are used, including differences in the nature and intensity of use. Consequently, access to technology does not necessarily translate into equivalent outcomes.

Within healthcare, meaningful use is important because digital technologies generate value through their incorporation into professional activities. Regular and integrated use can facilitate information retrieval, communication, coordination and decision-making, whereas limited or fragmented use may restrict these benefits (25). Accordingly, this study conceptualises perceived digital health benefits as a downstream outcome of digital technology use and proposes:

H4

Usage access is positively associated with perceived digital health benefits among healthcare workers in public district hospitals.

Skills Access and Perceived Digital Health Benefits

Skills access represents an important dimension of meaningful digital access because technological availability alone does not ensure that users can derive value from digital technologies. Van Dijk's Resource and Appropriation Theory positions skills as a critical stage in the process through which individuals appropriate digital technologies, while van Deursen and van Dijk (17) distinguish operational, informational and strategic skills as important components of meaningful digital use. In healthcare settings, these capabilities enable professionals to navigate digital systems, evaluate information and integrate digital technologies into routine work. Evidence among healthcare professionals similarly indicates that digital literacy and capability are relevant to digital health implementation and perceived usefulness (26,27). Greater skills access may therefore enable healthcare workers to derive greater work-related benefits from digital technologies, including improved efficiency, coordination and service delivery (28). Accordingly, the study hypothesised that:

H5

Skills access is positively associated with perceived digital health benefits among healthcare workers in Ghana's public district hospitals.

The hypothesised relationships among the study constructs are presented in Fig. 1.

Rural-Urban Digital Inequality

Geographical location remains an important dimension of digital inequality in health systems (29). Rural health facilities often operate with greater constraints in connectivity, electricity, digital infrastructure and technical support, which can limit their ability to implement and sustain digital health technologies (19,23,30). These differences can affect not only technology availability but also the capacity of health workers to develop skills and incorporate digital technologies into routine practice.

Evidence from Ghana similarly suggests that digital health implementation varies across geographical contexts. Affran et al. (13) identified unreliable electricity and internet connectivity and limited digital skills as important constraints in rural settings, while urban implementations were more frequently associated with interoperability, bureaucratic and organisational challenges. Letsa et al. (14) also highlighted how telemedicine can help address geographical barriers to healthcare in Ghana, although unstable connectivity, limited access to devices and logistical constraints can restrict its effectiveness. These findings suggest that the rural-urban digital divide should be examined as a multidimensional health-system issue rather than solely as a difference in physical infrastructure.

Materials and Methods

Study Design and Setting

This study employed a quantitative, comparative cross-sectional design to examine rural-urban differences in digital health access among healthcare workers in public district hospitals in Ghana. The study was theoretically informed by van Dijk's Resource and Appropriation Theory, which conceptualises digital inequality as a multidimensional process involving motivational, material, skills and usage access (6). Consistent with this perspective, the study examined whether differences in the conditions surrounding digital health use extended beyond physical access to include digital skills, patterns of technology use and perceived benefits.

The study was conducted in 20 public district hospitals in Ghana, comprising 10 hospitals located in rural settings and 10 located in urban settings. The rural-urban classification was based on the geographical location of the participating hospitals and was determined by the research team prior to analysis. District hospitals were selected to provide a broadly comparable level of healthcare delivery across the two geographical settings while allowing examination of differences in the digital environments within which healthcare workers operated. The study therefore treated rural-urban location as a contextual grouping variable rather than assuming that all district hospitals were inherently rural or that all non-rural facilities were urban.

The study focused on healthcare workers because they constitute direct users of digital health technologies within healthcare organisations. Their ability to access, acquire skills in and use digital technologies may influence the extent to which digital health systems become embedded in routine service delivery. The focus on healthcare workers also enabled the study to examine digital inequality at the provider and facility level rather than directly measuring patient-level health inequities.

Study Population and Sampling

The study population comprised healthcare workers employed in the selected public district hospitals. Eligible participants were healthcare workers who used, or were expected to use, digital technologies in connection with their work. The study included healthcare workers from different professional categories, including nurses, doctors, midwives, allied health professionals and health administration or management personnel.

Participants were eligible if they were currently employed at one of the selected hospitals, had experience with digital health or other work-related digital technologies for at least six months, and provided informed consent to participate. Healthcare workers whose roles did not require the use of digital technologies were excluded, as were individuals who did not meet the minimum experience requirement. The eligibility criteria were intended to ensure that participants had sufficient exposure to the digital health environment to provide informed assessments of access, skills, usage and perceived benefits.

Sampling

A multistage convenience sampling approach was used. First, public district hospitals were identified according to their geographical setting, with the sampling frame structured to include comparable numbers of rural and urban hospitals. Twenty hospitals were subsequently included, consisting of 10 rural and 10 urban district hospitals. This balanced facility structure provided a basis for comparing digital health conditions across the two geographical settings.

Second, healthcare workers within the selected hospitals were invited to participate. The study targeted approximately 20 respondents from each participating hospital, resulting in a planned sample of approximately 400 healthcare workers. Of the 384 responses obtained, 9 were excluded due to incomplete data, yielding a final analytical sample of 375 respondents.

The distribution of respondents across hospitals was broadly balanced, consistent with the sampling strategy. Rural and urban participants were retained as separate analytical groups based on the predetermined classification of their hospitals. Rural-urban location was not determined from participants' individual perceptions or self-reported residential location.

Data Collection

Data were collected using a structured, self-administered questionnaire. To accommodate differences in access to digital devices and Internet connectivity among healthcare workers, two modes of questionnaire administration were used. Participants could complete either a paper-based questionnaire or an equivalent electronic version administered through Google Forms. The two versions contained the same substantive questions, response options and construct measures.

The use of both paper and electronic modes was intended to minimise the possibility that participation would itself be influenced by differences in digital access. Hospital-level focal persons assisted with the distribution and collection of questionnaires and facilitated participant access to the electronic survey where applicable. Participation was voluntary, and respondents were informed about the purpose of the study before completing the questionnaire.

The data collection procedure was designed to obtain responses from healthcare workers across different professional categories and across both rural and urban hospital settings. Completed questionnaires were reviewed for completeness before inclusion in the analytical dataset. The final dataset contained 375 unique respondents.

Measurement of Study Constructs

The study constructs were operationalised using a theory-informed approach that combined established conceptualisations, empirical measures and context-specific item adaptation. Van Dijk's Resource and Appropriation Theory provided the overarching conceptual basis for motivational, material, skills and usage access (31). Measurement development was further informed by research on digital access and

skills (6,8,31) and the FICTA instrument for ICT access among professional user (12). Items were adapted and contextualised to reflect digital health use within Ghanaian public district hospitals.

Material Access (MAT). Material access was measured using nine items assessing the availability and adequacy of digital devices and supporting infrastructure. The items covered access to appropriate devices, availability of computers or other digital devices, functionality of available devices, Internet reliability, network stability, electricity reliability, availability of backup power, technical support and the resolution of technical problems. The construct was grounded in van Dijk's material access dimension and informed by the multifaceted conceptualisation of digital access and FICTA (6,9,12,31). The items were contextualised to the infrastructural requirements of digital health use in public hospitals.

Skills Access (SK). Skills access was measured using nine items covering operational, informational and strategic aspects of digital competence. The items assessed respondents' ability to operate digital technologies, navigate digital health systems, perform routine digital tasks without assistance, search for relevant information, determine the relevance of digital information, interpret information obtained through digital technologies, use technology to improve work activities, use digital information to support decision-making and identify ways in which digital technologies could improve work processes. Item development was primarily informed by the digital skills framework of (17) complemented by van Dijk's (16) broader access framework and (12). The construct was therefore intended to capture the capacity to use digital technologies meaningfully rather than simply the ability to access them.

Usage Access (UA). Usage access was assessed using six items measuring the frequency, regularity, integration and breadth of digital technology use. The items assessed regular use of digital technologies, use when required, frequency of reliance on digital technologies, integration of digital technologies into routine work, use across multiple aspects of work and the ability to use information from one digital system in conjunction with another. Usage access was informed by van Dijk's usage-access dimension and research demonstrating that digital inequality increasingly manifests through differences in the extent, intensity and patterns of technology use (8,9,31).

Perceived Digital Health Benefits (DHB). Perceived digital health benefits were measured using six items assessing respondents' perceptions of whether digital technologies improved work efficiency, enabled tasks to be completed more quickly, improved service delivery, enhanced coordination, increased responsiveness and reduced duplication of work. The construct was specified as a downstream outcome of digital access and use rather than as a component of van Dijk's access framework. Its operationalisation was informed by literature concerning the perceived benefits and implications of digital health technologies for healthcare professionals and health service (11,24,28).

Except for Usage Access, all reflective construct items were measured using five-point agreement scales ranging from 1 = strongly disagree to 5 = strongly agree. Usage Access was measured using a five-point frequency scale ranging from 1 = never to 5 = very often. Higher scores represented higher levels of the respective construct.

Results

Participant Characteristics

The study obtained complete demographic information for 375 respondents, comprising 182 participants from rural hospitals and 193 from urban hospitals. The demographic characteristics of the respondents are presented in Table 1. The distribution of respondents across rural and urban hospitals was broadly comparable with respect to demographic and professional characteristics. No statistically significant rural–urban differences were observed in gender, $\chi^2(1) = 0.105$, $p = .746$; age group, $\chi^2(4) = 3.507$, $p = .477$; professional category, $\chi^2(5) = 1.814$, $p = .874$; highest educational qualification, $\chi^2(5) = 7.455$, $p = .189$; years of professional experience, $\chi^2(4) = 0.869$, $p = .929$; or years at the current hospital, $\chi^2(4) = 1.749$, $p = .782$.

In contrast, substantial rural–urban differences were observed in respondents' exposure to digital-health training and technology use. Prior digital-health training was reported by 30.2% of rural respondents compared with 84.5% of urban respondents, with the difference being statistically significant, $\chi^2(1) = 113.209$, $p < .001$. Similarly, 14.3% of rural respondents reported receiving digital-health training during the previous 12 months, compared with 81.9% of urban respondents, $\chi^2(1) = 171.175$, $p < .001$. Frequency of digital-health use also differed significantly between the two groups, $\chi^2(4) = 38.377$, $p < .001$. Among rural respondents, 20.9% reported never using digital health and 24.2% reported rare use, compared with 8.8% and 16.6%, respectively, among urban respondents. Conversely, very frequent digital-health use was reported by 4.9% of rural respondents compared with 25.4% of urban respondents.

Table 1
Respondent Characteristics by Hospital Location

Characteristic	Category	Rural (n = 182)	Urban (n = 193)	Total (N = 375)	χ^2	p
Gender	Female	114 (62.6%)	124 (64.2%)	238 (63.5%)	0.105	.746
	Male	68 (37.4%)	69 (35.8%)	137 (36.5%)		
Age group (years)	20–29	38 (20.9%)	44 (22.8%)	82 (21.9%)	3.507	.477
	30–39	69 (37.9%)	65 (33.7%)	134 (35.7%)		
	40–49	41 (22.5%)	50 (25.9%)	91 (24.3%)		
	50–59	30 (16.5%)	25 (13.0%)	55 (14.7%)		
	≥60	4 (2.2%)	9 (4.7%)	13 (3.5%)		
Professional category	Allied health professional	37 (20.3%)	34 (17.6%)	71 (18.9%)	1.814	.874
	Doctor	22 (12.1%)	22 (11.4%)	44 (11.7%)		
	Health administration/management	19 (10.4%)	16 (8.3%)	35 (9.3%)		
	Midwife	19 (10.4%)	18 (9.3%)	37 (9.9%)		
	Nurse	76 (41.8%)	92 (47.7%)	168 (44.8%)		
	Other	9 (4.9%)	11 (5.7%)	20 (5.3%)		
Highest education	Certificate	20 (11.0%)	14 (7.3%)	34 (9.1%)	7.455	.189
	Diploma	50 (27.5%)	68 (35.2%)	118 (31.5%)		
	Bachelor's degree	85 (46.7%)	83 (43.0%)	168 (44.8%)		
	Master's degree	21 (11.5%)	15 (7.8%)	36 (9.6%)		

Characteristic	Category	Rural (n = 182)	Urban (n = 193)	Total (N = 375)	χ^2	p
	Doctorate	5 (2.7%)	9 (4.7%)	14 (3.7%)		
	Other	1 (0.5%)	4 (2.1%)	5 (1.3%)		
Professional experience (years)	<5	50 (27.5%)	51 (26.4%)	101 (26.9%)	0.869	.929
	5–9	60 (33.0%)	58 (30.1%)	118 (31.5%)		
	10–14	37 (20.3%)	40 (20.7%)	77 (20.5%)		
	15–19	22 (12.1%)	28 (14.5%)	50 (13.3%)		
	≥20	13 (7.1%)	16 (8.3%)	29 (7.7%)		
Years at current hospital	<2	40 (22.0%)	42 (21.8%)	82 (21.9%)	1.749	.782
	2–4	48 (26.4%)	58 (30.1%)	106 (28.3%)		
	5–9	57 (31.3%)	51 (26.4%)	108 (28.8%)		
	10–14	28 (15.4%)	29 (15.0%)	57 (15.2%)		
	≥15	9 (4.9%)	13 (6.7%)	22 (5.9%)		
Prior digital-health training	Yes	55 (30.2%)	163 (84.5%)	218 (58.1%)	113.209	<.001
	No	127 (69.8%)	30 (15.5%)	157 (41.9%)		
Training in past 12 months	Yes	26 (14.3%)	158 (81.9%)	184 (49.1%)	171.175	<.001
	No	156 (85.7%)	35 (18.1%)	191 (50.9%)		
Frequency of digital-health use	Never	38 (20.9%)	17 (8.8%)	55 (14.7%)	38.377	< .001
	Rarely	44 (24.2%)	32 (16.6%)	76 (20.3%)		

Characteristic	Category	Rural (n = 182)	Urban (n = 193)	Total (N = 375)	χ^2	p
	Sometimes	57 (31.3%)	51 (26.4%)	108 (28.8%)		
	Often	34 (18.7%)	44 (22.8%)	78 (20.8%)		
	Very often	9 (4.9%)	49 (25.4%)	58 (15.5%)		

Rural-Urban Differences in Digital Health Access and Perceived Benefits

Descriptive statistics for the five study constructs are presented in Table 2. Rspondents in rural hospitals reported lower mean scores than urban hospitals across all constructs except motivational access, where the difference was minimal.

Table 2
Descriptive Statistics for Study Constructs by Hospital Location

Construct	Rural M (SD)	Urban M (SD)	Mean Difference
Motivational Access	2.87 (0.80)	2.99 (0.92)	−0.11
Material Access	2.25 (0.72)	3.47 (0.67)	−1.22
Skills Access	2.69 (0.75)	3.23 (0.80)	−0.54
Usage Access	2.55 (0.75)	3.20 (0.78)	−0.65
Perceived Benefits	2.71 (0.71)	3.10 (0.76)	−0.39

Measurement Model Assessment

The measurement model was assessed using partial least squares structural equation modelling (PLS-SEM) with SmartPLS. The assessment considered indicator reliability, internal consistency reliability, convergent validity, and discriminant validity. All constructs demonstrated satisfactory internal consistency reliability (Table 3). Cronbach's alpha values ranged from 0.892 to 0.951, and composite reliability (rho_C) values ranged from 0.917 to 0.958, both exceeding the recommended threshold of 0.70. Convergent validity was supported by average variance extracted (AVE) values ranging from 0.649 to 0.718, all exceeding the recommended threshold of 0.50.

Table 3
Reliability and Convergent Validity

Construct	Cronbach's α	Composite Reliability (rho_C)	AVE
Material Access	0.951	0.958	0.718
Skills Access	0.935	0.945	0.657
Usage Access	0.915	0.934	0.702
Perceived Benefits	0.892	0.917	0.649

Structural Model Assessment

The structural model was evaluated using bootstrapping with 5,000 subsamples. Four of the five specified structural relationships were statistically significant. The results are presented in Table 4. Material access was positively associated with skills access ($\beta = 0.513$, $t = 7.473$, $p < .001$), supporting H1. Material access was also positively associated with usage access ($\beta = 0.282$, $t = 3.015$, $p = .003$), supporting H3. Skills access was positively associated with usage access ($\beta = 0.362$, $t = 4.237$, $p < .001$), supporting H2. Finally, usage access was positively associated with perceived digital health benefits ($\beta = 0.548$, $t = 6.521$, $p < .001$), supporting H4.

In contrast, skills access was not significantly associated with perceived digital health benefits ($\beta = -0.050$, $t = 0.536$, $p = .592$). Thus, there was no evidence of a direct association between skills access and perceived digital health benefits after accounting for usage access.

The model explained 26.4% of the variance in skills access ($R^2 = 0.264$), 31.6% of the variance in usage access ($R^2 = 0.316$), and 27.5% of the variance in perceived digital health benefits ($R^2 = 0.275$). The bootstrap 95% confidence intervals for R^2 were 0.147–0.422 for skills access, 0.190–0.470 for usage access, and 0.174–0.435 for perceived digital health benefits.

Effect-size estimates indicated that the contribution of the structural relationships varied across the model. Material access had a relatively large effect on skills access ($f^2 = 0.358$), while its effect on usage access was small ($f^2 = 0.086$). Skills access had a small effect on usage access ($f^2 = 0.141$), whereas its direct effect on perceived digital health benefits was negligible ($f^2 = 0.003$). Usage access had a comparatively substantial effect on perceived digital health benefits ($f^2 = 0.308$). These findings indicate that usage access made an important contribution to explaining perceived digital health benefits, whereas skills access had little direct explanatory contribution once usage access was included in the model.

Table 4
Structural Model Results

Hypothesis	Path	β	t	p	95% CI	Supported?
H1	Material Access → Skills Access	0.513	7.473	<.001	[0.377, 0.647]	Yes
H2	Skills Access → Usage Access	0.362	4.237	<.001	[0.195, 0.528]	Yes
H3	Material Access → Usage Access	0.282	3.015	.003	[0.097, 0.466]	Yes
H4	Usage Access → Perceived Benefits	0.548	6.521	<.001	[0.383, 0.713]	Yes
H5	Skills Access → Perceived Benefits	−0.050	0.536	.592	[− 0.233, 0.133]	No

Rural-Urban Subgroup Results

The structural model was subsequently estimated separately for rural and urban district hospitals to examine whether the relationships displayed different patterns across geographical contexts. The subgroup estimates are presented in Table 5. Among rural hospitals, material access was positively associated with usage access (β = 0.291, p = .032), while the association between material access and skills access did not reach statistical significance (β = 0.343, p = .082). Similarly, skills access was not significantly associated with usage access (β = 0.081, p = .661). Usage access, however, was positively associated with perceived digital health benefits (β = 0.511, p < .001). The direct association between skills access and perceived digital health benefits was also not significant (β = −0.003, p = .987).

Among urban hospitals, material access was positively associated with skills access (β = 0.494, p < .001), and skills access was positively associated with usage access (β = 0.544, p < .001). In contrast, the direct association between material access and usage access was not statistically significant (β = 0.147, p = .227). Usage access remained positively associated with perceived digital health benefits (β = 0.605, p < .001), while skills access was not directly associated with perceived digital health benefits (β = −0.081, p = .582).

Table 5
Structural Model Results by Hospital Location

Path	Complete β	Rural β	Rural p	Urban β	Urban p
MAT → SK (H1)	0.513	0.343	.082	0.494	<.001
SK → UA (H2)	0.362	0.081	.661	0.544	<.001
MAT → UA (H3)	0.282	0.291	.032	0.147	.227
UA → DHB (H4)	0.548	0.511	<.001	0.605	<.001
SK → DHB	−0.050	−0.003	.987	−0.081	.582

Discussion

This study examined whether digital health inequality among healthcare workers in public district hospitals is limited to differences in technology availability or extends across multiple dimensions of digital access. Drawing on van Dijk's Resource and Appropriation Theory, the study considered motivational, material, skills and usage access and examined their relationships with perceived digital health benefits. The findings indicate that the rural-urban divide was not evident in motivation, but was pronounced in material access, skills access, usage access and perceived digital health benefits. The structural model further showed that material access was positively associated with skills access and usage access, skills access was positively associated with usage access, and usage access was positively associated with perceived digital health benefits. In contrast, skills access did not have a significant direct association with perceived benefits once usage access was included in the model. Taken together, these findings support a multidimensional understanding of digital inequality in healthcare in which differences extend beyond the availability of technologies to the conditions, capabilities and patterns of use surrounding digital health.

Theoretical implications

The study has three main theoretical implications. First, it demonstrates the relevance of Van Dijk's Resource and Appropriation Theory to digital health within healthcare organisations. Much of the digital health equity literature has focused on patients, households and service users. By examining healthcare workers, this study extends the digital inequality perspective to the provider and facility level. The findings indicate that digital inequality can be observed among workers who operate within the same national health system (32) but encounter different material and organisational conditions across geographical settings.

Second, the study provides empirical support for distinguishing Skills Access from Usage Access (33). The constructs were empirically distinct in the measurement model, and their structural relationships were also different. Skills Access was positively associated with Usage Access, whereas Skills Access did not show a significant direct association with Perceived Digital Health Benefits, once Usage Access

was included. This distinction suggests that digital capability and digital use should not be treated as interchangeable dimensions of healthcare workers' digital readiness (34,35).

Third, the findings reinforce the importance of treating digital inequality as contextually embedded (36). The rural-urban comparison showed that inequalities were concentrated in material access, skills, usage and perceived benefits rather than motivation. This suggests that digital inequality within health systems cannot be understood solely through individual characteristics. Organisational infrastructure, training opportunities, technical support and the broader environment in which technologies are used are also relevant to understanding how digital health capacity is distributed (10,37).

Practical implications

The findings have several implications for digital health policy and implementation in Ghana and comparable settings. First, infrastructure and workforce capability should be addressed together. The association between Material Access and Skills Access indicates that digital capability develops within a material environment. Reliable devices, connectivity, electricity, backup power and technical support should therefore be considered alongside workforce development when planning digital health investments (38).

Second, training should be sustained rather than treated solely as a one-time implementation activity. The substantial rural-urban difference in training exposure suggests that workforce development opportunities are unevenly distributed across facilities. Continuing professional development, refresher training and practical support could complement initial system training, particularly as digital health systems evolve (39).

Third, implementation monitoring should move beyond deployment indicators. The findings suggest that the presence of digital systems does not provide sufficient information about the extent to which healthcare workers are using them. Monitoring frameworks could therefore incorporate measures of frequency, breadth and integration of digital health use alongside conventional indicators of system availability.

Fourth, equity-oriented digital health planning should account for differences in facility context. The findings indicate that rural and urban healthcare workers did not experience the same digital access environment. This supports consideration of context-sensitive implementation strategies that respond to differences in infrastructure, training, technical support and organisational conditions rather than assuming that a uniform intervention will produce equivalent opportunities for digital health use across facilities.

Finally, provider-level digital equity has potential implications for patient-facing digital health equity. If healthcare workers in rural facilities have fewer opportunities to access, develop and use digital technologies, this may limit the extent to which patients in those settings benefit from digital health investments. However, this downstream relationship was not directly examined in the present study.

Future research should therefore investigate whether differences in provider-level digital access translate into differences in patient access, quality of care, service responsiveness or health outcomes.

Limitations

Several limitations should be considered when interpreting the findings. First, the cross-sectional design limits causal inference. The structural relationships identified in the PLS-SEM analysis are associations that are consistent with the theoretical framework, but they cannot establish that material access causes skills development or that usage causes perceived benefits. Longitudinal research would be needed to examine how digital capabilities and patterns of use develop over time, particularly as digital systems are introduced, expanded or modified.

Second, the study relied on self-reported measures. Respondents' perceptions of access, skills, usage and benefits may differ from objectively observed infrastructure conditions, system-generated usage or organisational performance. Future research could combine survey data with facility audits, system usage records, training records and objective service indicators.

Third, the measurement instruments were theory-informed and contextually adapted rather than adopted unchanged from a single validated instrument. Although the constructs demonstrated satisfactory reliability, convergent validity and discriminant validity, adaptation may mean that some aspects of the original conceptualisations were not fully captured. Further validation across different healthcare settings would strengthen the measurement framework.

Fourth, Perceived Digital Health Benefits were measured from the perspective of healthcare workers rather than through objective measures of patient outcomes, organisational performance or service quality. The findings therefore concern perceived work-related benefits and should not be interpreted as evidence that digital health use directly improves patient safety, quality of care or health equity.

Finally, the model did not include several organisational and contextual factors that may influence digital health use, including leadership support, digital health governance, interoperability, workload, staffing and financing. Incorporating these factors in future research could provide a more comprehensive explanation of how material resources and workforce capabilities interact within healthcare organisations.

Conclusion

This study examined rural-urban differences in digital health access among healthcare workers in Ghana's public district hospitals through the lens of Van Dijk's Resource and Appropriation Theory. The findings indicate that digital inequality extends beyond the availability of technology. Rural and urban respondents reported similar levels of motivation to engage with digital health, but differed substantially in Material Access, Skills Access, Usage Access and Perceived Digital Health Benefits. The largest rural-urban disparity occurred in Material Access, while differences were also evident in digital skills, usage and perceived benefits.

The structural model further showed that Material Access was positively associated with Skills Access and Usage Access, Skills Access was positively associated with Usage Access, and Usage Access was positively associated with Perceived Digital Health Benefits. Skills Access did not have a significant direct association with Perceived Digital Health Benefits after Usage Access was included in the model. These findings support a layered understanding of digital inequality in which material conditions, capabilities and patterns of use represent distinct but related dimensions of digital health access.

The findings suggest that equitable digital transformation requires more than deploying technologies across healthcare facilities. It also requires attention to the material and organisational conditions that enable healthcare workers to develop digital capabilities, use digital systems routinely and derive meaningful work-related benefits from them. In the Ghanaian district hospital context, addressing these conditions may contribute to reducing geographical disparities in digital health opportunity. Whether such provider-level differences ultimately translate into differences in patient-level access, quality or health outcomes remains an important question for future research.

Declarations

Ethics approval and consent to participate

Institutional authorization to conduct the study was granted by Komfo Anokye Teaching Hospital (KATH). The principal researcher was introduced as a staff member of KATH, and the research topic and proposed study were stated in the authorization letter. The letter provided institutional authorization for the research to be conducted at the selected health facilities. The authorization letter, together with the participant information and consent materials, was submitted to the respective facilities before data collection. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Participation was voluntary, and informed consent was obtained from all participants before completion of the questionnaire. No separate approval from an institutional ethics committee or IRB was obtained for this study.

Funding

The authors received no specific funding for this study.

References

1. Ahmed MM, Okesanya OJ, Olaleke NO, Adigun OA, Adebayo UO, Oso TA, et al. Integrating Digital Health Innovations to Achieve Universal Health Coverage: Promoting Health Outcomes and Quality Through Global Public Health Equity. Healthcare. 2025 May 5;13(9):1060. doi:10.3390/healthcare13091060
2. Barbieri C, Neri L, Stuard S, Mari F, Martín-Guerrero JD. From electronic health records to clinical management systems: how the digital transformation can support healthcare services. Clin Kidney J. 2023 Oct 31;16(11):1878–84. doi:10.1093/ckj/sfad168

3. Haimi M. The tragic paradoxical effect of telemedicine on healthcare disparities- a time for redemption: a narrative review. BMC Med Inform Decis Mak. 2023 May 16;23(1):95. doi:10.1186/s12911-023-02194-4
4. Bhaskar S, Bradley S, Chattu VK, Adisesh A, Nurtazina A, Kyrykbayeva S, et al. Telemedicine as the New Outpatient Clinic Gone Digital: Position Paper From the Pandemic Health System REsilience PROGRAM (REPROGRAM) International Consortium (Part 2). Front Public Health. 2020 Sep 7;8:410. doi:10.3389/fpubh.2020.00410
5. Vallée A, Arutkin M. The Transformative Power of Virtual Hospitals for Revolutionising Healthcare Delivery. Public Health Rev. 2024 Jun 19;45:1606371. doi:10.3389/phrs.2024.1606371
6. Van Dijk J. The Deepening Divide: Inequality in the Information Society [Internet]. 2455 Teller Road, Thousand Oaks California 91320 United States: SAGE Publications, Inc.; 2005 [cited 2026 Sep 26]. Available from: https://sk.sagepub.com/books/the-deepening-divide doi:10.4135/9781452229812
7. Richardson S, Lawrence K, Schoenthaler AM, Mann D. A framework for digital health equity. Npj Digit Med. 2022 Aug 18;5(1):119. doi:10.1038/s41746-022-00663-0
8. Deursen AJAMV, Van Dijk JAGM. Measuring Internet Skills. Int J Hum-Comput Interact. 2010 Sep 17;26(10):891–916. doi:10.1080/10447318.2010.496338
9. Van Laar E, Van Deursen AJAM, Van Dijk JAGM, De Haan J. The relation between 21st-century skills and digital skills: A systematic literature review. Comput Hum Behav. 2017 Jul;72:577–88. doi:10.1016/j.chb.2017.03.010
10. Erku D, Khatri R, Endalamaw A, Wolka E, Nigatu F, Zewdie A, et al. Digital Health Interventions to Improve Access to and Quality of Primary Health Care Services: A Scoping Review. Int J Environ Res Public Health. 2023 Sep 28;20(19):6854. doi:10.3390/ijerph20196854
11. Olu O, Muneene D, Bataringaya JE, Nahimana MR, Ba H, Turgeon Y, et al. How Can Digital Health Technologies Contribute to Sustainable Attainment of Universal Health Coverage in Africa? A Perspective. Front Public Health. 2019 Nov 15;7:341. doi:10.3389/fpubh.2019.00341
12. Soomro KA, Kale U, Curtis R, Akcaoglu M, Bernstein M. Development of an instrument to measure Faculty's information and communication technology access (FICTA). Educ Inf Technol. 2018 Jan;23(1):253–69. doi:10.1007/s10639-017-9599-9
13. Affran S, Mensah MSB, Agyei SK, Nyamah EY, Tackie G. Implementation of digital health innovations in Ghana: a systematic review. Discov Soc Sci Health. 2026 Mar 14;6(1):67. doi:10.1007/s44155-026-00394-7
14. Letsa BS, Oppong J, Ahmed H, Kubio C, Adofo AO, Amu H, et al. Role of telemedicine in bridging the healthcare gap: application of the hub and spokes model in the Hohoe Municipality, Ghana. Front Digit Health. 2026 Aug 12;8:1864794. doi:10.3389/fdgth.2026.1864794
15. Nyarko S, Atinga RA, Bardoe D, Owusu AN. Digital health system integration in Ghana: a scoping review of governance arrangements, interoperability aspirations, and regulatory gaps. BMC Health Serv Res. 2026 Mar 9;26(1):529. doi:10.1186/s12913-026-14324-5

16. Van Dijk J. The Deepening Divide: Inequality in the Information Society [Internet]. 2455 Teller Road, Thousand Oaks California 91320 United States: SAGE Publications, Inc.; 2005 [cited 2026 Sep 29]. Available from: https://sk.sagepub.com/books/the-deepening-divide doi:10.4135/9781452229812
17. Deursen AJAMV, Van Dijk JAGM. Measuring Internet Skills. Int J Hum-Comput Interact. 2010 Sep 17;26(10):891–916. doi:10.1080/10447318.2010.496338
18. Van Dijk JAGM. Digital Divide: Impact of Access. In: Rössler P, Hoffner CA, Zoonen L, editors. The International Encyclopedia of Media Effects [Internet]. 1st ed. Wiley; 2017 [cited 2026 Sep 29]. p. 1–11. Available from: https://onlinelibrary.wiley.com/doi/10.1002/9781118783764.wbieme0043 doi:10.1002/9781118783764.wbieme0043
19. Hui CY, Abdulla A, Ahmed Z, Goel H, Monsur Habib GM, Teck Hock T, et al. Mapping national information and communication technology (ICT) infrastructure to the requirements of potential digital health interventions in low- and middle-income countries. J Glob Health. 2022 Dec 29;12:04094. doi:10.7189/jogh.12.04094
20. Kaboré SS, Ngangue P, Soubeiga D, Barro A, Pilabré AH, Bationo N, et al. Barriers and facilitators for the sustainability of digital health interventions in low and middle-income countries: A systematic review. Front Digit Health. 2022 Nov 28;4:1014375. doi:10.3389/fdgth.2022.1014375
21. Van Laar E, Van Deursen AJAM, Van Dijk JAGM, De Haan J. The relation between 21st-century skills and digital skills: A systematic literature review. Comput Hum Behav. 2017 Jul;72:577–88. doi:10.1016/j.chb.2017.03.010
22. Ferreira JC, Elvas LB, Correia R, Mascarenhas M. Empowering Health Professionals with Digital Skills to Improve Patient Care and Daily Workflows. Healthcare. 2025 Feb 5;13(3):329. doi:10.3390/healthcare13030329
23. Okeke EB, Forman D, Taylor E, Hyde E, Parente F, Kanmodi KK, et al. Barriers and facilitators to digital health adoption: a thematic analysis of healthcare professionals' perspectives in rural Oyo State, Nigeria. BMC Digit Health. 2025 Nov 18;3(1):85. doi:10.1186/s44247-025-00227-8
24. Wang M, Huang K, Li X, Zhao X, Downey L, Hassounah S, et al. Health workers' adoption of digital health technology in low- and middle-income countries: a systematic review and meta-analysis. Bull World Health Organ. 2025 Feb 1;103(02):126-135F. doi:10.2471/BLT.24.292157
25. Abbas R, Miller T. Exploring communication inefficiencies in disaster response: Perspectives of emergency managers and health professionals. Int J Disaster Risk Reduct. 2025 Apr;120:105393. doi:10.1016/j.ijdrr.2025.105393
26. Kasaye MD, Kebede N, Kalayou MH, Kebede SD, Molla A. Digital health literacy and associated factors among health professionals during the outbreak of corona virus pandemic in Ethiopia: A systematic review and meta-analysis. Digit Health. 2024 Jan;10:20552076241271799. doi:10.1177/20552076241271799
27. Tegegne MD, Tilahun B, Mamuye A, Kerie H, Nurhussien F, Zemen E, et al. Digital literacy level and associated factors among health professionals in a referral and teaching hospital: An implication for

future digital health systems implementation. Front Public Health. 2023 Apr 11;11:1130894. doi:10.3389/fpubh.2023.1130894

28. Thapa S, Nielsen JB, Aldahmash AM, Qadri FR, Leppin A. Willingness to Use Digital Health Tools in Patient Care Among Health Care Professionals and Students at a University Hospital in Saudi Arabia: Quantitative Cross-sectional Survey. JMIR Med Educ. 2021 Feb 19;7(1):e18590. doi:10.2196/18590
29. Khan MH, Patel B, Raza M, Saji AS, Ahsan A, Singh PK, et al. Geographical Disparities in Accessing and Utilizing Digital Health and Strategies to Mitigate These Disparities: A Literature Review. Health Sci Rep. 2026 May;9(5):e72479. doi:10.1002/hsr2.72479
30. Akhtar MN, Haleem A, Javaid M. Scope of health care system in rural areas under Medical 4.0 environment. Intell Pharm. 2023 Dec;1(4):217–23. doi:10.1016/j.ipha.2023.07.003
31. Van Dijk JAGM. Digital Divide: Impact of Access. In: Rössler P, Hoffner CA, Zoonen L, editors. The International Encyclopedia of Media Effects [Internet]. 1st ed. Wiley; 2017 [cited 2026 Sep 26]. p. 1–11. Available from: https://onlinelibrary.wiley.com/doi/10.1002/9781118783764.wbieme0043 doi:10.1002/9781118783764.wbieme0043
32. Zheng Y, Walsham G. Inequality of what? An intersectional approach to digital inequality under Covid-19. Inf Organ. 2021 Mar;31(1):100341. doi:10.1016/j.infoandorg.2021.100341
33. Richardson S, Lawrence K, Schoenthaler AM, Mann D. A framework for digital health equity. Npj Digit Med. 2022 Aug 18;5(1):119. doi:10.1038/s41746-022-00663-0
34. Alwali J, Alwali W, Yahya S. Digital health transformation and innovation behavior: examining the role of technological readiness and dynamic capabilities in public hospitals. Int J Innov Sci. 2025 Sep 25. doi:10.1108/IJIS-05-2025-0243
35. Alotaibi N, Wilson CB, Traynor M. Enhancing digital readiness and capability in healthcare: a systematic review of interventions, barriers, and facilitators. BMC Health Serv Res. 2025 Apr 4;25(1):500. doi:10.1186/s12913-025-12663-3
36. Robinson L, Cotten SR, Ono H, Quan-Haase A, Mesch G, Chen W, et al. Digital inequalities and why they matter. Inf Commun Soc. 2015 May 4;18(5):569–82. doi:10.1080/1369118X.2015.1012532
37. Khan R, Khan S, Almohaimeed HM, Almars AI, Pari B. Utilization, challenges, and training needs of digital health technologies: Perspectives from healthcare professionals. Int J Med Inf. 2025 May;197:105833. doi:10.1016/j.ijmedinf.2025.105833
38. Vinci S, Kwong LH, Miles SB, McCord R, Cady G, Tang K, et al. Reliable electricity to advance quality health care in low-resource settings. Lancet Glob Health. 2026 Apr;14(4):e626–39. doi:10.1016/S2214-109X(25)00537-6
39. Soleas EK, Dittmer D, Waddington A, Van Wylick R. Demystifying Artificial Intelligence for Health Care Professionals: Continuing Professional Development as an Agent of Transformation Leading to Artificial Intelligence–Augmented Practice. J Contin Educ Health Prof. 2025 Jan;45(1):52–5. doi:10.1097/CEH.0000000000000571

Figures

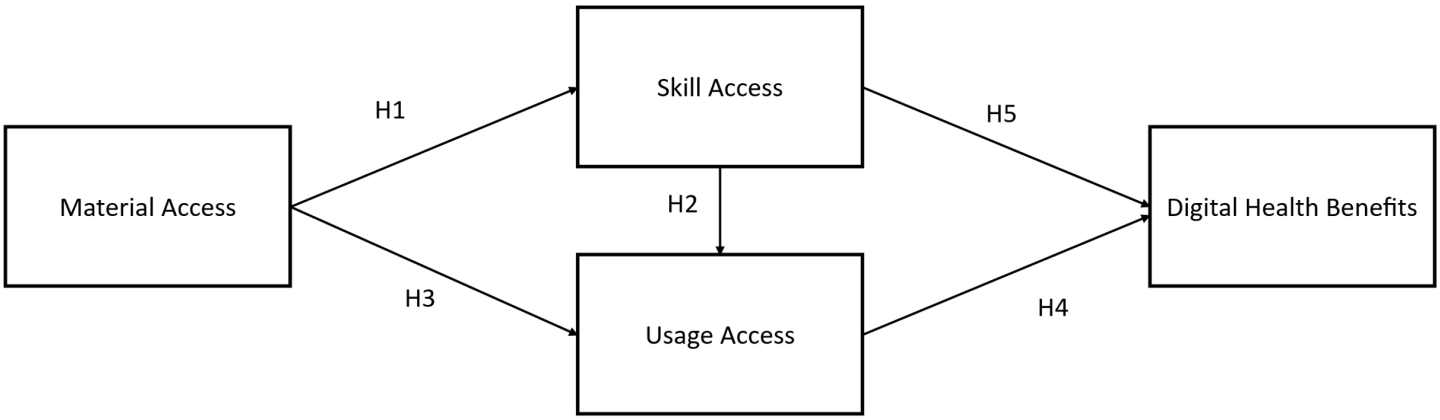


Figure 1

Conceptual framework

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryMaterial.docx
- SupplementaryMaterial1.docx
- Instrument.docx